

Response to Reviewer # 2's Comments

Overall Comment *This manuscript presents a detailed analysis of the raindrop size distribution (DSD) during wet and dry spells of the Indian Summer Monsoon over Western Ghats of India. The DSD data are collected from a Joss-Waldvogel disdrometer during June-September of 2012-2015. DSD characteristics, including the diurnal variation and DSD spectra at different rain rates, as well as the gamma distribution parameters in different types of rainfall (i.e., stratiform vs convective) are summarized.*

Response *Overall, this paper is easy to follow. However, it is still not clear what the authors have addressed in addition to showing the DSD characteristics. Further discussions are required to elaborate the physical reasoning in this analysis.*

We are indebted to the reviewer for his valuable and thoughtful comments on the manuscript. We much appreciate the reviewer's time and efforts during the evaluation of the manuscript. We went through all the referee comments and suggestions and implemented the same in the revised manuscript. Point-to-point clarifications for referee's comments and how we have addressed each recommendation is given below. The manuscript is also altered by considering the other referee's comments.

The present study investigates the raindrop size distribution (DSD; which provides indirect inference on rain microphysical processes such as collision, coalescence, breakup, evaporation, etc. that can shape the DSD) differences during the wet and dry spells of Indian Summer Monsoon (ISM) on the Western Ghats (WGs) region. Till now, there are limited studies of DSDs exist in the WGs region by considering long-term dataset. For the first time, the authors attempted to understand the DSD characteristics by considering the monsoon intra-seasonal oscillations (wet and dry spells). The present study brings out the results of a unique opportunity by analysing extensive data set and also considering the different phases of the monsoon intra-seasonal oscillations on the WGs region.

To understand the dynamical mechanisms responsible for the different DSD characteristics during wet and dry spells, the background dynamical parameters like temperature, specific humidity is studied using the ERA-Interim data along with the rain rate measurements from JWD. A separate section in the manuscript is there to discuss the dynamical processes responsible for the observed DSD differences.

Specific Comments

Comment. 1 *First of all, I do not really see anything new in this manuscript. The analysis methods are rather conventional, and the findings are not well highlighted. The authors should elaborate more on the motivation and novelty of this study. More importantly, the authors should provide sufficient discussion and explanation about the DSD characteristics indicated in the observations.*

Response **From the earlier studies of Ramamurthy (1969), active and break spells of**

the ISM have been extensively studied, especially during the last two decades (e.g., Goswami and Ajaya Mohan, 2001; Gadgil and Joseph, 2003; Kripalani et al., 2004; Waliser, 2006; Uma et al., 2011; Mohan and Rao, 2012; Rajeevan et al., 2013; Das et al., 2013; Rao et al., 2016). The characteristic features of these active and break spells have been well understood; for example, their identification (Rajeevan et al., 2006; Rajeevan et al., 2010), spatial distribution (Ramamurthy, 1969; Rajeevan et al., 2010; Ratan and Venugopal, 2013), circulation patterns (Goswami and Ajaya Mohan 2001; Rajeevan et al., 2010), vertical wind and thermal structure (Uma et al., 2011), rainfall variability (Deshpande and Goswami, 2014; Rao et al., 2016) and the macro- and micro-physical features of clouds (Rajeevan et al., 2013; Das et al., 2013). Even though different dynamical mechanisms for the observed rainfall distribution during the wet and dry spells are well understood, however, the microphysical processes of rain formation is still lacking.

Hence, there is a need to study the DSD characteristics using the long-term dataset, especially in the WGs region. In addition, no study aimed at understanding the DSD characteristics during monsoon intra-seasonal oscillations till now, owing to the importance of wet and dry spells on the ISM. These gaps areas motivated the authors to analyse the DSD characteristics using long-term datasets during the wetter and drier phases of the ISM over WGs. This study aims to provide a better understanding of the DSD characteristics (which provide indirect inference on rain microphysical processes such as collision, coalescence, breakup, evaporation, etc. that can shape the DSD) at these intra-seasonal time scales.

The author's used the conventional methods in the analysis because these methods are robust to understand the DSD characteristics during the wet and dry spells. Using these methods, we attempted to study the DSD characteristics for the first time during the wet and dry periods of ISM in the WGs region. This study showed a clear difference in DSDs between wet and dry spells of the ISM. These differences provide an indirect inference of rain microphysics during the wet and dry periods, also suggesting the potential requirement for different microphysical parameterization schemes in the numerical models.

The atmospheric background conditions/meteorological parameters are used to discuss the physical mechanisms responsible for different DSD characteristics during the wet and dry spells. For this, the latest reanalysis dataset, ERA-Interim, along with JWD data, is used. A separate section is included to discuss the dynamical processes responsible for the observed DSD differences over WGs.

Comment. 2 *In addition, I have serious concerns about using single point data to resolve the*

orographic enhancement. Justification is required from this perspective.

Response The authors have not discussed orographic impacts on precipitation formation and DSD using a single ground-based disdrometer. In this work, authors only discussed the DSD characteristics (indirectly rain microphysics) during the wet and dry periods of ISM. An attempt has also been made to understand the physical mechanism of DSD variations during the wetter and drier periods of ISM. Authors have used GPM products to provide a general overview of DSD variation with topography during the monsoon season. The limited dataset from GPM has restricted our further analysis of DSD variation with topography during the wet and dry spells of ISM.

Comment. 3 *I am not convinced by the interpretation of the orographic gradients using GPM products. Also, the authors should incorporate the uncertainties in GPM retrievals. In fact, I do not really think this manuscript will have significant impact without including more in-situ data.*

Response This manuscript aims to examine the characteristics of DSD using disdrometer measurements during the drier and wetter periods of the ISM in the WGs region. Earlier studies have shown that the WGs precipitation processes can be modulated by the complex topography (Konwar et al., 2014; Utsav et al., 2017, etc.). Hence, in the present study, the GPM analysis is used to provide an overview of the DSD distribution over this topographic region irrespective of wet and dry spells of ISM. Such a review is not possible with single point-wise observation. Examining the orographic impact on DSD was one of the reviewer's requirements, which was addressed and included in the manuscript. The authors also believe that such analysis is useful in understanding the underlying rain microphysical processes (indirect inference on collision-coalescence, breakup, evaporation, etc. that can shape the DSD) at different altitudes. Moreover, the parameterization schemes in the numerical models also demand the dominant microphysical processes like collision-coalescence, breakup, etc. at a finer resolution. Hence, it is necessary to have the rain microphysical observations at different locations over the complex topography. At this point, the reviewer's suggestion can be considered for future work.

The GPM-DPR can estimate the rain integral parameters, D_m , and N_w using dual-frequency ratio (DFR) method. The DSD parameterization used in the GPM-DPR is the gamma distribution with a constant shape parameter, $\mu=3$. The constant value of ' μ ' introduces errors in the retrievals. The retrieval of D_m using the DFR method is iterative, and the D_m has two solutions when the DFR is less than 0. The uncertainties in the GPM-DPR in estimating the DSD are detailed in Seto et al., (2013), Liao et al., (2014), etc. Recently, Krishna et al. (2017) assessed the DSD measurements from GPM on the WGs region by comparing them with the ground-based disdrometer. They

showed that the seasonal variations in D_m and N_w are well represented in the GPM measurements, however, underestimate in comparison to the ground-based disdrometer measurement. Radhakrishna et al. (2016) also found that the GPM underestimates and overestimates the mean D_m and N_w during the southwest and northeast monsoons over Gadanki, a semiarid region of India. In the present study, the authors intend to show the variability of DSDs over the complex terrain, not the absolute value. Hence, it is reasonable to consider the GPM measurements to present the overview of DSD over the complex topography.

The single point-wise instrument deployed at the mountain peak of WGs is not sufficient to address the orographic impacts on the DSDs. One of the difficulties in studying the effect of orography is the unavailability of the in-situ data (like disdrometer network) over the WGs region (windward and leeward slopes). It is a well-accepted suggestion to examine the effect of orography on DSDs by deploying an observational network of disdrometers and rain gauges along the windward and leeward slopes of the WGs. This suggestion can be addressed in future works.

The relative sentences have been added in the revised manuscript.

Comment. 4 *The authors have included analyses and figures from many perspectives. But, none of them has been detailed in a very quantitative manner. In fact, the reviewer was not even clear about what problems the authors are trying to address except the detailed illustration of DSD characteristics. Significant revisions are requested to highlight the scientific merits.*

Response As per the reviewer's suggestion, the authors put their sincere effort to concise the manuscript with the clear objectives and better representation of results.

Comment. 5 *Anyway, the authors started from an interesting point about orographic precipitation. But I did not see sufficient investigation on this aspect.*

Response The motivation of the present study is to understand the DSD (which provides indirect inference on rain microphysical processes such as collision-coalescence, breakup, evaporation, etc. that can shape the DSD) characteristics at the intra-seasonal time scales over WGs. This provides an insight into the rain microphysical processes that are inferred from DSD differences between wet and dry spells precipitation. However, to have an impression of DSD over the topographic region, the authors included an overview of DSD on three different locations on the WGs. The inclusion of DSD variation with topography was also the requirement of one of the reviewers. Further non-availability of sufficient dataset, the GPM analysis is restricted to provide the overall view of the DSD irrespective of the intra-

seasonal oscillations. The impact of orography on the DSD distributions during wet and dry spells is important and will be taken up in future works.

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